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THE DYNAMICS OF DEPOSIT INSURANCE AND THE CONSUMPTION TRAP

Hans Gersbach

Jan Wenzelburger*

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CESifo

Center for Economic Studies & Ifo Institute for Economic Research

Poschingerstr. 5, 81679 Munich, Germany

Phone: +49 (89) 9224-1410 - Fax: +49 (89) 9224-1409

e-mail: office@CESifo.de

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Abstract

We investigate a banking system subject to repeated macroeconomic shocks and show that without deposit rate control, the banking system collapses with certainty. Any initial level of reserves will delay the collapse but not avoid it. Even without a banking collapse, the economy still converges to a consumption trap with positive probability. Savings are maximal in the consumption trap, but are used entirely to pay back obligations of banks. No long-term investments can be financed and GDP is minimal. We discuss stronger intervention rules that avoid both a collapse and the consumption trap, confirming that capital requirements are an early indicator signaling when intervention may become necessary. Our analysis provides an explanation why economies which experience a banking crisis may endure long-lasting economic downturns.

Keywords: Financial intermediation, macroeconomic risks, banking crises, deposit insurance, banking regulation.

JEL Classification: D41, E4, G2.

Hans Gersbach
Alfred-Weber-Institut
University of Heidelberg
Grabengasse 14
69117 Heidelberg
Germany
Gersbach@uni-hd.de

Jan Wenzelburger
University of Bielefeld
P.O.Box 100 131
33501 Bielefeld
Germany

1 Introduction

In the last decades, the frequency of severe banking crises has increased significantly. The devastation that they bring to an economy, including the budgetary consequences of government bail-outs, has created a lot of attention concerning the optimal design of banking regulation. While there are many important studies examining the behavior of banks, a dynamic general equilibrium perspective of a banking system exposed to repeated macroeconomic shocks is missing.

In this paper we argue that such a dynamic general equilibrium perspective provides complementary insights as well as additional challenges for the regulation of the banking system. We consider an overlapping generations model in which financial intermediaries solve agency problems between saving agents and investing entrepreneurs by economizing on transaction costs in financial contracting. In every period, the productivity of entrepreneurs is subject to macroeconomic shocks. There is either explicit or implicit deposit insurance. In the latter case, large set–up costs of banks or high costs of financial disruption caused by a collapse of the banking sector will implicitly insure deposits of the elder generation. In order to ensure that banks meet their obligations, a regulator can intervene in the banking sector by enforcing capital requirements and deposit rate ceilings. Our major conclusions are as follows.

First, without any intervention, the banking system collapses with certainty. This result is caused by the asymmetric impact of macroeconomic shocks on bank reserves and by the inability of the banking system to recover from losses. Positive macroeconomic shocks will yield high returns for firms, but profits of banks remain zero. A sufficiently negative shock causes a decline in the repayment capacity of firms and thus losses of banks. To cover losses, banks need new funds on which they have to pay interest. As a consequence, banks' losses increase over time independent of macroeconomic shocks, thereby causing a collapse of the system after sufficiently many periods. It is a striking fact that this collapse will occur with certainty for *any* initial level of reserves prescribed by some capital adequacy rule if average repayments per unit of loan are too low.

Second, we identify a serious inefficiency when regulatory intervention aims at just avoiding a banking collapse. Such an intervention rule requires that obligations can be paid back in any macroeconomic environment for all future periods. In this case, losses of banks will increase over time, but can always be covered by new funds from short term production. The economy converges to a (deterministic) steady state with positive probability, called consumption trap, in which new funds must be used entirely to pay back deposit obligations in each period. Profitable but risky long-term investments cannot be financed anymore and aggregate income is minimal.

Third, we discuss the nature of deposit rate intervention rules that avoid both a collapse and the consumption trap. Such intervention rules require limits on the discretion of a generation to intervene when an adverse macroeconomic environment causes losses for the banking system. We establish conditions under which the consumption trap can be avoided. While such intervention rules must be considerably stronger than those which just avoid a collapse, early intervention prevents an economy from being stuck with a banking system that produces losses and low aggregate income for a long time. Capital requirements can be justified as an early indicator for the necessity of interventions with deposit controls.

Fourth, our paper points to two non-standard relationships between macroeconomic aggregates in the presence of banking systems and deposit insurance. On the one hand, aggregate income and last-period aggregate savings are negatively associated; high saving indicates high deficits of the banking system and therefore less investments generating income in the next period. On the other hand, the observation of a high number of bankruptcies of firms can either indicate an adverse macroeconomic environment or, for a given situation, high profits of banks and thus high future aggregate income. In the latter case, a large share of bankrupt firms is associated with high loan interest rates and thus with high intermediation margins.

Finally, the model in our paper offers an explanation of the phenomenon that economies with a troubled banking system may experience long-lasting recessions. Since new funds must be used to pay out old depositors, aggregate investment and aggregate income will be low in subsequent periods. The banking system can only gradually recover from the crisis by accumulating retained earnings. As a consequence, the economy may remain in a state of low aggregate income for many periods. This might explain why some countries experiencing banking crises have endured long-lasting recessions.

2 Relation to the Literature

Our results are directly linked to the literature on bank competition and banking regulation. Comprehensive surveys with different emphasis can be found in Bhattacharya & Thakor (1993), Dewatripont & Tirole (1994), Hellwig (1994), Freixas & Rochet (1997), Bhattacharya, Boot & Thakor (1998), and Allen & Santomero (1998). As discussed extensively in the literature, deposit insurance invites banks to seek excessive portfolio risks, which necessitates regulatory restrictions such as cash-asset and risk-sensitive capital requirements in order to limit risks. In our paper, return characteristics of projects are not subject to risk-seeking incentives, but regulatory actions are needed to avoid a collapse or low aggregate income when the banking system is exposed to repeated macroeconomic shocks.

The question of banking regulation in the presence of macroeconomic shocks has received relatively little attention. The one important contribution is Blum & Hellwig (1995), who have shown that strict capital adequacy rules may reinforce macroeconomic fluctuations. Our analysis suggests that capital requirements have a useful role as an early indicator of when to intervene with deposit rate control or other measures that could restore a sufficient level of bank equity. Deposit rate control induces higher profits for banks and allows intermediaries to absorb negative macroeconomic shocks without running into a collapse. In this respect, profit accumulation of the banking system can insure depositors from aggregate fluctuations intertemporally at the cost of lower returns on savings. The intertemporal smoothing of the risk characteristics of financial intermediaries has been developed and pointed out by Allen & Gale (1997).

Gersbach (1998) and Hellman, Murdock & Stiglitz (1998) showed that capital requirements alone cannot prevent banking crises and that other interventions such as deposit rate controls may be necessary to keep banks from gambling. In our analysis, we abstract from incentive considerations at an individual banking institution and examine the interventions necessary to avoid banking crises and situations in which aggregate income becomes minimal. Our conclusions suggest that only strong deposit intervention rules can prevent a collapse and the consumption trap even though no gambling problem is present.[1]

The paper develops a model in which financial intermediation with adverse selection and moral hazard can be integrated into a macroeconomic framework with overlapping generations. It follows the tradition of business cycle models with financial intermediation starting with Williamson (1987) and Uhlig (1995) who focuses on collapse problems in transition economies. Our most important innovation is a model in which the banking system is subject to repeated macroeconomic shocks, while at the same time there are economic gains from insuring deposits.

In the large bulk of the literature assessing banking crises, recent estimates show that the costs of banking crises may become very high (e.g., see Caprio & Klingebiel (1997), Lindren, Gracia & Saal (1996), Caprio & Honohan (1999), Peter (1999)). In showing that banking crises may lead to strong and long-lasting declines in GDP, this fact is qualitatively captured in our model.[2]

3 Model

3.1 Macroeconomic environment

Consider a standard overlapping generations (OG) model with financial intermediation in which agents live for two periods. Time is infinite in the forward direction and divided into discrete periods indexed by t. Each generation consists of a continuum of agents, indexed by [0,1], which are divided into two classes. A fraction η of the individuals are potential entrepreneurs, the rest $1-\eta$ of the population are consumers. Potential entrepreneurs and consumers differ in the fact that only the former have access to investment technologies. There is one physical good that can be used for

[1] Calomiris (1997) provides an authoritative perspective on the rise of a bank safety net, referring to deposit insurance and bail-out. He suggests to increase the discipline of private creditor monitoring by requiring banks to issue subordinate debt.

[2] Banking crises rarely come alone, and when crises appear jointly the real effects are the most severe. There is an emerging literature that relates different types of crises, such as banking crises with debt crises, currency crises, and asset market crashes and suggest remedies to reduce financial instability. See for instance Bernanke (1983), Mishkin (1996), Kaminsky & Reinhart (1998), Chang & Velasco (1998), Sachs & Radelet (1998), Caballero & Krishnamurthy (1998), Rogoff (1999).

consumption or investment. Each individual in each generation receives an endowment e of the goods when young and none when old. The endowment can also be understood as arising from short-term production labor which is supplied inelastically and produces the endowment e within each period.[3]

Each entrepreneur has access to a production project with a fixed size that converts time t goods into time $t+1$ goods. The required funds for an investment project are $e+I$. An entrepreneur must borrow I units of the goods in order to undertake the investment project. The entrepreneurs are heterogeneous and indexed by a quality parameter i which is uniformly distributed on $[0, \eta]$. If an entrepreneur of type i obtains additional resources I and decides to invest, he realizes investment returns in the next period of

$$f_i(q, e+I) = (1+i)\, q f(e+I), \tag{1}$$

where f denotes a standard atemporal neoclassical production function. The parameter $q \in \mathbb{R}_+$ is subject to exogenous stochastic noise which is governed by a stationary ergodic process on $\mathbb{R}_+$. $\underline{q}$ is the lowest realization of the macroeconomic shock q.

For simplicity, we assume that potential entrepreneurs are risk neutral and only care about consumption when old, i.e., they do not consume when young. Consumers consume in both periods. They have utility functions $u(c_t^1, c_t^2)$ defined over consumption in the two periods, where c_t^1, c_t^2 are the consumption plans of the consumer born in period t when young and old, respectively. For tractability, we assume that when households do not face any risks, the interest rate elasticity of savings is zero. This occurs e.g. when utility is given by

$$u(c_t^1, c_t^2) = \ln(c_t^1) + \delta \ln(c_t^2), \tag{2}$$

where $\delta\,(0 < \delta < 1)$ is the discount factor. If a household can transfer wealth between periods at a real interest rate r_t under certainty, the standard solution of the households problem generates savings, denoted by s, which are given by:

$$s = \frac{\delta\, e}{1+\delta}. \tag{3}$$

3.2 Intermediation

We assume that there are $n (n > 1)$ banks, indexed by $j = 1, \ldots, n$, that can finance entrepreneurs. Banks are owned by the entrepreneurs. Transfer of ownership of banks to the next generation occurs through bequests.[4] Each bank j can sign deposit contracts $D(r_j^d)$, where $1 + r_j^d$ is the repayment offered for 1 unit of resources. Loan contracts of

[3] It can be useful to interpret endowments as a result of short-term production. To simplify language, we use the terms endowment and production instead of short-term and long-term production.

[4] This is made for simplification. Otherwise, we would have to consider a stock market for bank shares.

bank j are denoted by $C(r_j^c)$, while $1 + r_j^c$ is the repayment required from entrepreneurs for 1 unit of funds. All deposits and loan contracts last for one period.

Our assumptions about deposits and loan contracts are closely related to the problem of how banks can or should deal with macroeconomic risk. Hellwig (1998) points out that banks could shift macroeconomic risk to their depositors by offering deposit contracts that are contingent on easily observable macroeconomic indicators such as interest rates or gross domestic product. We assume that - in coincidence with the current practice - deposit contracts are not conditioned on technology shocks and that the macroeconomic risk remains on bank's balance sheets. This is justified in the following way: First, as in Hellwig (1998), by the inflexibility of indexed deposit rates as a risk management tool, the existence of transaction costs, and by the market making role of banks.[5] Second, by the fact that macroeconomic indicators are only an incomplete measure for exposure to aggregate risk and that these indicators is difficult to assess.

Depositors face the following informational asymmetries. The quality i is known to the entrepreneur, but not to depositors. Moreover, depositors cannot verify whether or not an entrepreneur invests (see Gersbach & Uhlig 1997). To alleviate such agency problems in financial contracting, financial intermediation can act as delegated monitoring in the sense of Diamond (1984).[6] As delegated monitors, banks act as information producers about private investment projects. Banks have access to monitoring technologies by screening applicants in order to assess their credit worthiness when contracts are negotiated as well as by interim or ex-post monitoring when entrepreneurs execute their investment projects or in the case they default.

In focusing on the impact of macroeconomic shocks on banks and GDP, we assume that banks can completely alleviate agency problems through contracts[7] or, equivalently, that monitoring outlays per credit contract are negligible for banks. Our analysis carries over to the case where banks can completely alleviate agency problems by investing a fixed amount per credit contract in monitoring. In this case, the interest rate spread will be positive and will cover the costs of monitoring in equilibrium. For simplicity of presentation, we assume in this paper that such fixed monitoring costs are zero.

Note that generations save and invest independently. Generations are only connected by financial intermediaries, which are the sole long-living institution. A new generation is only affected by the history of their predecessor's accumulated profits or losses. In the former case, profits are accumulated as reserves or are distributed as dividends among current shareholders. In the latter case, a generation may want to rescue banks

[5]Note that Hellwig points out that today's most common way to reduce macroeconomic risk exposure is third party contracting. Risk is often transfered to other banks and hence our analysis applies to them. Moreover, banks that shift their risk to third parties are still exposed to credit risk that is likely to be correlated with the macroeconomic risk they want to insure against.

[6]A succinct discussion about the underlying frictions in markets that lead to intermediation is found in Hellwig (1994).

[7]See also Williamson (1987), for general equilibrium models with financial intermediation in which costly monitoring alleviates agency problems.

by reimbursing depositors or they may be forced by regulation to do so. We assume that set–up costs for banks are prohibitively high, so that every generation will always support a workout of banks rather than providing rescue funds for a (forced) bankruptcy. An alternative interpretation are financial disruption costs which, if large enough, would cause a young generation to support the workout of a crisis in the banking sector.

4 Intermediation Equilibria and Regulation

4.1 Intermediation game

We discuss the intermediation game which takes place in each period. Dropping the time index in this section, we distinguish between two possible intermediation games. In the first scenario, the regulator is absent and banks set deposit and loan rates. In the second scenario, the regulator fixes the interest rate on deposits, denoted by r^{dreg}. The timing of actions in the economy within a typical period t is as follows.

1. Old entrepreneurs pay back with limited liability. The current deficits or reserves are determined. Reserves are distributed among shareholders according to payout rules.

2. In the first scenario banks set interest rates on deposits and loans. In the second scenario either banks' realized profits are too low or they have made losses. Then a regulator will intervene by setting fixed interest rate on deposits. Banks will set interest rates on loans and offer deposit contracts to consumers as well as deposit and credit contracts to entrepreneurs.

3. Consumers and entrepreneurs decide which contracts to accept. Resources are exchanged and banks pay back depositors.

4. Young entrepreneurs produce subject to a macroeconomic shock.

The main assumptions of the intermediation game in both scenarios are as follows. We first assume that banks cannot ration deposit contracts in stage 3.[8] Loans are constrained by the amount of deposits obtained. Second, we assume that interest rates on deposits are guaranteed by deposit insurance or by the workout incentive of the next generation. That is, consumers and saving entrepreneurs face no risk in accepting a deposit contract with a promised interest rate.

In order to focus on how a banking system can deal with repeated macroeconomic shocks, we assume that entrepreneurs make loan application decisions under the assumption that they will not be rationed by the banks. If entrepreneurs were rejected

[8]This assumption coincides with current regulations in most countries.

nevertheless, they go to a bank with the highest deposit interest rate and save. This assumption is a useful shortcut for a full-fledged analysis of different rationing schemes and rationing expectations. The assumption can only be justified, however, if the same equilibria in terms of interest rates and investment allocations occur for less myopic rationing schemes. In Gersbach (1998) it is shown that this is the case for the static intermediation game which we use as a building block in this paper.[9]

Under the no-rationing assumption, all entrepreneurs applying for a loan contract go to the banks with the lowest loan interest rate. Let r^d denote the maximum interest rates offered to depositors. In the first scenario, r^d is equal to $\max_j\{r_j^d\}$, where bank j offers r_j^d, and equal to r^{dreg} in the second scenario. Similarly, let r^c denote the minimal borrowing rate demanded by banks. That is, $r^c = \min_j\{r_j^c\}$. Moreover, we denote by $\pi(i, r^c, q)$ the profit of an investing entrepreneur of quality i encountering the macroeconomic shock q which is given by:

$$\pi(i, r^c, q) = \max\left\{(1+i)\, q\, f(e+I) - I(1+r^c), 0\right\}. \tag{4}$$

Given some loan interest rate r^c, the expected profit of an investing entrepreneur i is then

$$\Pi(i, r^c) := \mathbb{E}[\pi(i, r^c, \cdot)] = \int_{\mathbb{R}_+} \max\{(1+i)q\, f(e+I) - I(1+r^c), 0\}\, \mu(dq), \tag{5}$$

where μ denotes the probability distribution of the shocks. Note that $\Pi(i, r^c)$ is monotonically increasing in quality levels i and monotonically decreasing in loan rates r^c.

To examine the entrepreneurs' decision whether to apply for loans or to save, notice that for offered loan contracts of size I, entrepreneurs must use all of their equity e to reach the required project size $e + I$. Therefore, entrepreneurs face a binary decision problem.[10] An entrepreneur of quality i applies for loans and wants to invest if and only if

$$\Pi(i, r^c) \geq e(1 + r^d). \tag{6}$$

Suppose that $\Pi(0, 0) > e$, meaning that the entrepreneur with the lowest quality level can, on average, invest for a zero interest rate. Since $\Pi(i, r^c)$ is monotonically increasing in i, there is a unique critical quality level $i^G = i^G(r^c, r^d)$, defined through

[9]Gersbach (1998) considers three rationing schemes. First, myopic or self-fulfilling no-rationing as assumed in this paper. Second, under simple rationing entrepreneurs take into account that they may be rationed by the bank at which they apply for credits. Third, under complex rationing entrepreneurs apply first for loans at the bank with the lowest loan rate. If they are rejected they may try the second bank. As shown in Gersbach (1998), all three rationing schemes lead to the same perfect Bayesian equilibrium in which banks make zero profits and no rationing occurs.

[10]A challenging and non-trivial extension of the model is to allow for a portfolio decision over investment and saving. To keep the model analytically as tractable as possible, we exclude diversified portfolios.

$\Pi(i^G, r^c) = e(1 + r^d)$, so that all entrepreneurs with $i \geq i^G$ invest and entrepreneurs with $i < i^G$ save their endowments. Note that $i^G(r^c, r^d)$ is monotonically increasing in r^d and monotonically increasing in r^c. Moreover, since banks are able to secure repayments, they do not have to worry about low-quality entrepreneurs applying for loans. Low-quality entrepreneurs are always better off with saving endowments.

4.2 Intermediation equilibria

In order to derive the intermediation equilibrium, we assume that banks are bailed out and deposits are ensured. Obviously, the feasibility of bail-outs has to be checked for all possible scenarios. To this end, we assume that investments exceed savings at zero deposit and loan interest rates for all possible realizations of the macroeconomic productivity shocks. We also assume that savings are never sufficient to fund all entrepreneurs. Since the interest rate elasticity of savings is zero, a sufficient condition is

$$S := (1 - \eta)\, s < \eta I. \tag{7}$$

Let d_t denote the banks' deficit ($d_t < 0$) or their reserves ($d_t \geq 0$) in period t. d_t is the difference between obligation at the beginning of the current period t and repayments of entrepreneurs who have invested in the last period $t-1$. Again, for convenience, we drop the time index in this section. If $d > 0$, banks have reserves that can be used for investments. If $d < 0$, the excess obligations must be covered by new funds obtained in the current period, which, however, can no longer be used for new investments. For the derivation of the intermediation equilibrium in this section, d is assumed to be given by activities of the banks in past periods.

There are two boundary values for d. Let $\overline{d} := \eta I - S$ denote the value of reserves that would allow all entrepreneurs to invest, since $S + \overline{d} = \eta I$ and $\overline{d} > 0$ by assumption. If $d > \overline{d}$, then banks have more reserves than needed to finance all entrepreneurs and hence resources are available in excess for any pair of deposit and loan interest rates. Similarly, let $\underline{d} := -[S + \eta e]$ denote the maximal deficit that still allows to balance liabilities in a particular period but not for new investments. For $d = \underline{d}$, all possible savings are needed to pay back obligations to the last generation. $\underline{d} < d$ ensures that there are enough saving entrepreneurs to finance new investment projects or to meet liabilities of the last generation. If $d < \underline{d}$, the banking system cannot fulfill its obligations anymore. The banking system as a whole is bankrupt and the economy collapses.

For these reasons, the intermediation problem arises only when $d \in [\underline{d}, \overline{d}]$. Assuming that depositors are fully protected through bail-outs of the next generation, a subgame perfect equilibrium of the intermediation game in the second scenario is a tuple

$$\left\{ \left\{ r_j^{d*} \right\}_{j=1}^{n}, \left\{ r_j^{c*} \right\}_{j=1}^{n} \right\}$$

such that entrepreneurs take optimal credit application and saving decisions and no bank has an incentive to offer different deposit or loan interest rates.

Proposition 1
Let $d \in [\underline{d}, \overline{d}]$.

A. *Suppose that banks set deposit and loan interest rates. Then there exists a unique equilibrium of the intermediation game with*

(i) $r^* = r_j^{c*} = r_j^{d*}, \quad j = 1, \dots, n;$

(ii) $r^* = r^*(d)$ *is determined by* $S + e\, i^G(r^*, r^*) + d = \left[\eta - i^G(r^*, r^*)\right] I.$

B. *Suppose that the regulator sets a deposit rate* $r^{dreg} \leq r^*(d)$*. Then, there exists a unique equilibrium of the intermediation game with*

(i) $r^{c*} = r_j^{c*}, \quad j, \dots, n;$

(ii) $r^{c*} = r^{c*}(d, r^{dreg})$ *is determined by*

$$S + e\, i^G(r^{c*}, r^{dreg}) + d = \left[\eta - i^G(r^{c*}, r^{dreg})\right] I,$$

where $r^{c*}(d, r^{dreg}) \geq r^*(d)$ *and* $r^{c*} = r^*(d)$ *if and only if* $r^{dreg} = r^*(d)$.

The proof of part **A** of proposition 1 is given in Gersbach (1998), Part **B** follows a similar logic. The intuition for part **B** is as follows. At r^{c*} banks can provide exactly the amount of loans demanded because savings and investments are balanced. By setting $r_j^c < r^{c*}$, bank j could attract all borrowers. Because deposit rates are fixed, savings can only be increased by rejecting borrowers who in turn will switch banks and save. The associated increase in the amount of loans for bank j will not outweigh the decrease in profits per loan and the deviation is not profitable. The case $r_j^c > r^{c*}$ is not profitable either. Since all borrowers would choose the bank offering r^{c*}, no borrowers would apply and bank j would simply face an excess of resources.

Without an intervention of a the regulator, Proposition 1 indicates that the intermediation game yields the competitive outcome in which savings and investments are balanced at a common interest rate for loans and deposits.[11]

An immediate consequence of Proposition 1 is that the critical entrepreneur $i^G = i^G(r^*, r^*)$ in the first scenario and $i^G = i^G(r^{c*}, r^{dreg})$ in the second scenario does not depend on interest rates since savings and investments are balanced in equilibrium. In equilibrium, this implies that i^G depends only on d, so that

$$i^G = i^G(d) := \frac{\overline{d} - d}{e + I}. \tag{8}$$

Notice that $i^G \in [0, \eta]$ if and only if $d \in [\underline{d}, \overline{d}]$. Combining the definition of the critical entrepreneur (6) and Proposition 1 yields:

[11] As discussed in Gersbach (1998), double-sided Bertrand competition yields competitive outcomes without a cornering of market sides by an individual bank as e.g. in Yanelle (1997) and Gehrig (1997). The reason for this fact is that entrepreneurs who are offered unfavorable credit terms will switch market sides and save their endowments.

Corollary 1
For each $d \in [\underline{d}, \overline{d}]$ *we have:*

(i) $r^*(\cdot)$ *is decreasing in reserve levels* d*;*

(ii) $r^{c*}(\cdot, r^{dreg})$ *is decreasing in reserve levels* d *for* $r^{dreg} \in [0, r^*(d)]$*;*

(iii) $r^{c*}(d, \cdot)$ *is decreasing in* r^{dreg} *for* $r^{dreg} \in [0, r^*(d)]$*.*

The last point of the corollary is of particular importance. If the regulator intervenes with a deposit rate $r^{dreg} < r^*(d)$, banks set higher loan interest rates in equilibrium than $r^*(d)$. By lowering deposit rates, a regulator will attract more entrepreneurs to apply for loans. Loan rates will therefore rise in order to deter some entrepreneurs from borrowing until savings and investments are again balanced. Thus, intervention causes positive intermediation margins and bank profits. Setting $r^{dreg} = r^*(d)$ amounts to the non-intervention case.

4.3 Regulatory instruments and dividend payments

In the last section, we introduced one possibility for the regulator to intervene in the financial market: ceiling deposit rates implies that positive intermediation margins obtain. However, it remains unspecified at which level of d the regulator will intervene and by how much. Mirroring existing regulation in the area of capital adequacy requirements,[12] we consider intervention rules that apply when reserves have fallen below a critical level determined by the credit volume of the banking system. We will explain later that without such interventions, banks may not be able to meet stipulated capital requirements in the future.

We consider a *(prospective) capital adequacy intervention rule*,[13] described as:

$$\textit{Intervention if and only if:} \quad \frac{d_t}{[\eta - i^G(d_t)]I} < \alpha,$$

Current reserves are related to the loans banks will acquire in the current period and $0 \leq \alpha \leq 1$. This intervention rule states that a regulator intervenes if current realized reserves fall below a certain threshold α as a percentage of the volume of realized loans

[12]The pros and cons of capital adequacy rules in the presence of bank moral hazard have been hotly debated in the literature (Dewatripont & Tirole (1994), Hellwig (1995), Holmström & Tirole (1997), and Gehrig (1996, 1997)). In our framework, capital requirements fulfill the traditional role of a buffer against aggregate shocks.

[13]Retrospective invention rules seem to be closer to real scenarios. We will work with the prospective rule, since then the model is one-dimensional. The qualitative results in this paper do not seem to depend on whether the rule is retrospective or prospective.

in the last period. The critical reserve level $d^{reg}(\alpha)$ below which a regulator takes action is independent of previous deficits and given by

$$d^{reg} = d^{reg}(\alpha) := \frac{-\alpha I \underline{d}}{e + I - \alpha I}. \tag{9}$$

Clearly, $d^{reg} = 0$ for $\alpha = 0$.

There are two possible scenarios. In the first one capital adequacy rules are strictly enforced, implying that banks lower their credit lines by reducing I or being forced to do so. In the second one, a regulator intervenes by putting a ceiling on the deposit rates. We consider the latter scenario and define an intervention rule by a function

$$\psi : [\underline{d}, \overline{d}] \longrightarrow \mathbb{R}_+, \quad r^{dreg} = \psi(d), \tag{10}$$

such that $\psi(d) \leq r^*(d)$ for all $d \in [\underline{d}, d^{reg}]$ and $\psi(d) = r^*(d)$ for all $d \in (d^{reg}, \overline{d}]$. The policy rule ψ is designed in such a way that the regulator intervenes with the otherwise competitive outcome if and only if $d_t \leq d^{reg}(\alpha)$. In doing so, $r^{c*}\big(d, \psi(d)\big)$ describes the loan interest rates for all values of $d \in [\underline{d}, \overline{d}]$; $\psi(d) = r^*(d)$ is equivalent to non-intervention.

Finally, we have to specify how banks distribute reserves among shareholders. If $d^{reg} \leq d_t \leq \overline{d}$, we assume that banks distribute $\beta(d_t - d^{reg})$ of its reserves to current shareholders with a payout ratio of $0 \leq \beta \leq 1$. The percentage β could be determined by bank managers, or the regulator might prescribe payout rules. A bank manager acting in the interest of current shareholders would set $\beta = 1$. Note that reserves are distributed among old entrepreneurs and, therefore, dividend prospects affect neither the savings and investment decisions of entrepreneurs nor the amount of savings and hence do not affect our intermediation results. If $d_t > \overline{d}$, we assume that all excess reserves $d_t - \overline{d}$ are distributed as dividends and the rest $\overline{d} - d^{reg}$ according to the first payout rule.

At this point it is important to point out that shareholders have an incentive to induce managers to distribute the maximum level of current reserves. So how can we have a banking system which starts with reserves or equity? There are two interpretations. First, capital requirements have forced banks to accumulate a certain reserve level in the past. Second, the banking system was operated in an oligopolistic or monopolistic manner in the past and entered tough price competition due to liberalization. Thus, our paper may be interpreted as the consequences of such a liberalization shock when a competitive banking system becomes subject to repeated macroeconomic shocks, starting with a certain reserve level inherited from the past.

5 Evolution of the Banking System

This section is devoted to the description of the evolution of reserves in a banking system. Adverse macroeconomic shocks may lead to bankruptcy of entrepreneurs and thus to repayments lower than $I(1+r^c)$. We assume that banks maximize the profits accruing to their shareholders. This implies that banks do not care about losses beyond the exhaustion of their capital base because losses are borne through bail-out by future generations and not by current shareholders. It turns out that the evolution of reserves is primarily driven by the capability of firms to pay back their loans in the presence of macroeconomic shocks.

5.1 Repayments of firms

Let $d \in [\underline{d}, \overline{d}]$ be the current level of reserves (deficits) at the beginning of an arbitrary period. Assume that the regulator has set the deposit interest rate in the last period to some value $r^{dreg} \leq r^*(d)$ and that the firms have encountered the shock q. Then banks will receive payments $P = P(d, q, r^{dreg})$ from all firms, given by

$$P(d, q, r^{dreg}) = \int_{i^G(d)}^{\eta} \min\Big\{(1+i)q\, f(e+I)\,,\, I\big(1+r^{c*}(d, r^{dreg})\big)\Big\} di. \tag{11}$$

Solving the integrals, firms' repayments are

$$P = \begin{cases} [\eta - i^G] I(1+r^{c*}) & \text{if } i^G = i^B, \\ qf(e+I)\left([\eta - i^G]\big(1+\frac{1}{2}(\eta + i^G)\big) - \frac{1}{2}[\eta - i^B]^2\right) & \text{if } i^G < i^B \leq \eta, \end{cases} \tag{12}$$

where

$$i^B = i^B(d, q, r^{dreg}) := \min\left\{\eta\,,\, \max\left\{i^G(d)\,,\, \frac{I\big(1+r^{c*}(d, r^{dreg})\big)}{qf(e+I)} - 1\right\}\right\} \tag{13}$$

denotes the entrepreneur with the lowest quality level, not bankrupt after encountering the shock q. All entrepreneurs with an average productivity of less than the loan interest factor go bankrupt. More precisely, (12) implies that repayments P are determined by the output of the mean investing entrepreneur with quality level $\frac{\eta + i^G}{2}$ minus the losses due to bankruptcies. Observe that a shock $q = 0$ causes complete bankruptcy, $i^B = \eta$. However, for $i^B < \eta$, (12) takes the form

$$P = [\eta - i^G] I(1+r^{c*}) - qf(e+I)\tfrac{1}{2}[i^B - i^G]^2.$$

The influence of the deficits on i^B depends on r^{c*} and on the technology. Due to Corollary 1, i^B decreases with r^{dreg} and q, respectively. Given a reserve level d, repayments P increase with r^{c*} and therefore with the number of bankruptcies as becomes apparent from Fig. 1. If loan interest rates are high, repayments to banks from firms are high which, in turn, increases the number of bankruptcies. As a consequence, P is decreasing in r^{dreg}, so that given some d, a regulator can maximize banks' profits and minimize next period's possible deficit d by setting $r^{dreg} = 0$ regardless of the magnitude of the shock. This means that a high number of bankruptcies may be a signal of high bank profits.

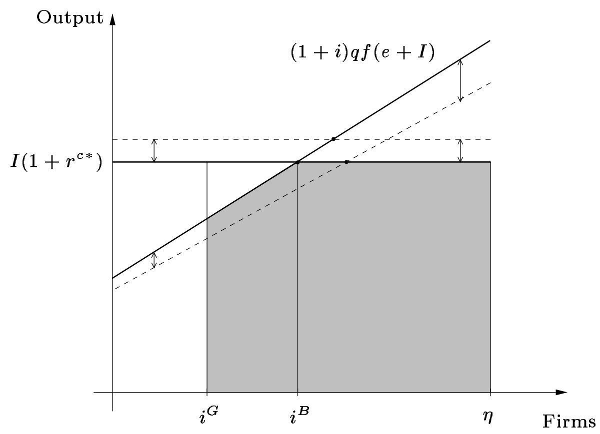

Figure 1: Repayment of banks.

We will see later on that the average repayment per unit of loan, given by

$$\frac{P(d,q,r^d)}{I[\eta - i^G(d)]}, \quad d > \underline{d},$$

is the crucial quantity driving the evolution of reserves. The most important observation is the following:

Proposition 2

Let ψ be a non-decreasing policy function. Then for each $q \in \mathbb{R}_+$, the average repayment per unit of loan $P\big(d,q,\psi(d)\big)/([\eta - i^G(d)]I)$ is non-increasing in reserve levels d.

Proof :

Let $d_0 < d_1 \in [\underline{d}, \overline{d})$ and $q \in \mathbb{R}_+$ be arbitrary but fixed. By the mean value theorem there exists $i_0 \in [i^G(d_0), \eta]$ with

$$\frac{P\big(d_0,q,\psi(d_1)\big)}{[\eta - i^G(d_0)]I} = \min\big\{(1+i_0)\,q\,f(e+I)/I,\; 1 + r^{c*}\big(d_0,\psi(d_1)\big)\big\}. \tag{14}$$

Since ψ is assumed to be non-decreasing, Corollary 1 and (14) imply

$$\begin{aligned}\frac{P\big(d_0,q,\psi(d_0)\big)}{[\eta - i^G(d_0)]I} &\geq \min\big\{(1+i_0)\,q\,f(e+I)/I,\; 1 + r^{c*}\big(d_0,\psi(d_1)\big)\big\} \\ &\geq \frac{P\big(d_1,q,\psi(d_1)\big)}{[\eta - i^G(d_1)]I}.\end{aligned}$$

Since $d_0 < d_1$ were arbitrary, this completes the proof.

■

The intuition of Proposition 2 is the following. Higher levels of d allow to finance a larger fraction of entrepreneurs. Therefore, the average quality level of investments declines. Simultaneously, higher levels of d imply lower loan interest rates. As a consequence of both effects, average repayments per unit of loan decline. Hence, as long as ψ is decreasing, average repayments are non-increasing in reserve levels. The same observation holds for the expected average repayments per unit of loan.

5.2 Evolution of deficits and income

Let $\underline{d} < d_t < \overline{d}$ denote the level of reserves (deficits) at the beginning of period t. Then banks raise funds $S + e\, i^G(d_t)$ that have to be payed back with interest at the end of period t. By Proposition 1, these funds are given by

$$S + e\, i^G(d_t) + d_t = I[\eta - i^G(d_t)], \quad d_t \in [\underline{d}, \overline{d}].$$

Assume for simplicity that the payout ratio β is zero. Given a policy rule ψ defined in (10), the new level of reserves (deficits) d_{t+1} is then determined by

$$d_{t+1} = G\big(d_t, q_t, \psi(d_t)\big), \quad d_t \in [\underline{d}, \overline{d}], \tag{15}$$

where for each q and each $r^d \geq 0$, the function $G(\cdot, q, r^d) : [\underline{d}, \overline{d}] :\to (-\infty, \overline{d}]$ is defined by

$$G(d, q, r^d) = \min\left\{\overline{d}\,,\; P(d, q, r^d) - \big[I[\eta - i^G(d)] - d\big]\,(1 + r^d)\right\}.$$

Equation (15) describes a random difference equation (Lasota & Mackey 1994), that can be viewed as the time-one map of a random dynamical system in the sense of Arnold (1998). Since we assume that $\{q_t\}_{t\in\mathbb{N}}$ is an i.i.d. process on a probability space $(\Omega, \mathcal{F}, \mathbb{P})$, the sequence of reserves $\{d_t\}_{t\in\mathbb{N}}$ generated by (15) is a Markov process. In particular, this implies that conditional expectations satisfy

$$\mathbb{E}_t[d_{t+1}] \equiv \mathbb{E}[d_{t+1}\,|d_t] = \mathbb{E}[G\big(d_t, \cdot, \psi(d_t)\big)], \quad t \in \mathbb{N},$$

cf. Bauer (1991, p. 134). If $d_{t+1} \geq 0$, then all depositors have been payed back and d_{t+1} represents the bank's reserves at the beginning of period $t+1$. If $\underline{d} < d_{t+1} < 0$, then the banks made losses and d_{t+1} is the amount of liabilities that could not be covered by loan repayments of entrepreneurs. Hence, banks in period $t+1$ have to raise enough new funds to pay back d_{t+1} to the depositors born in period t. If $d_{t+1} < \underline{d}$, then, as discussed above, banks are bankrupt and the economy collapses.[14]

Aggregate income in period t is given by

$$Y_t = e + \int_{i^G(d_t)}^{\eta} (1+i)q_t\; f(e+I)\,di. \tag{16}$$

[14]We tacitly assume that the systems will immediately be stopped as soon as d_t becomes less than $\underline{d}$. This implies that the process is always bounded.

Y_t depends on the realized macroeconomic shock and on the number of entrepreneurs who have invested in the last period. Since $i^G(d_t)$ is monotonically decreasing in d_t, Y_t is monotonically increasing in d_t for any realized macroeconomic shock. For $d_t = \underline{d}$, we have $i^G(d_t) = \eta$, $Y_t = e$. The economy is trapped since by Lemma 2, new investment projects can no longer be financed for $d_t = \underline{d}$. All new funds are used entirely to pay back old obligations. We call $d_t = \underline{d}$ the *consumption trap*, because no funds can be used for new investments.

Our economy exhibits a highly non-standard relationship between savings and aggregate income. Since savings are increasing in i_G and Y_t is decreasing in $i_G(d_t)$ aggregate income in period Y_t is negatively related to aggregate savings in period $t-1$. We obtain:

Lemma 1

(i) For any realization q_t, high aggregate savings $S + ei^G(d_t)$ in period t lead to low aggregate income Y_t.

(ii) In the consumption trap $d_t = \underline{d}$, aggregate savings in period t are maximal and equal to $S + \eta e$, while aggregate income Y_t is minimal and equal to e.

In the consumption trap the aggregate amount of savings is maximal because all potential entrepreneurs are saving. But since savings are fully used to pay back old deposits, no funds are available for investments and aggregate income in the next period is very low.

We close the section with two straightforward technical lemmas.

Lemma 2

For each $d \in [\underline{d}, \overline{d}]$ and $r^d \in [0, r^*(d)]$, we have

(i) $G(d, \cdot, r^d)$ is decreasing in realizations of shocks $q \in \mathbb{R}_+$ and

$$\underline{d}(1 + r^d) \leq G(d, 0, r^d) \leq G(d, q, r^d) \leq \overline{d}, \quad q \in \mathbb{R}_+.$$

(ii) $G(d, q, \cdot)$ is decreasing in r^d and, in particular,

$$G\big(d, q, r^*(d)\big) \leq G(d, q, r^d) \leq G(d, q, 0), \quad q \in \mathbb{R}_+.$$

An important consequence of Lemma 2 is that G is bounded from below and above. As a consequence, given any deficit $d_t \in [\underline{d}, \overline{d}]$, any shock q_t, and any regulator interest rate $r^{dreg} \in [0, r^*(d_t)]$, the subsequent deficit is always bounded from below and above. Note in particular that $G(\underline{d}, q, 0) = \underline{d}$ for all $q \in \mathbb{R}_+$. The second technical lemma, whose proof again is straightforward, relates expected average repayments to expected future deficits.

Lemma 3
For each $d \in (\underline{d}, \overline{d}]$ and each $r^d \in [0, r^*(d)]$, the following statements are equivalent:

$$(i) \qquad \mathbb{E}[G(d, \cdot, r^d)] \gtreqless d;$$

$$(ii) \qquad \mathbb{E}\left[\frac{P(d,\cdot,r^d)}{[\eta - i^G(d)]I}\right] \gtreqless 1 + \left(1 - \frac{d}{[\eta - i^G(d)]I}\right) r^d.$$

6 Collapse and Prevention

In this section we discuss the circumstances under which the economy will collapse and how a regulator can prevent such a collapse. We start with the observation that regulatory intervention is necessary to prevent a collapse of the economy.

6.1 Collapse without regulation

Consider the case without intervention. It follows from (12) that the best case in which all firms meet their obligations, that is $i^B = i^G$, is an upper bound for bank's repayments. Therefore

$$P\big(d, q, r^*(d)\big) \le [\eta - i^G(d)]\, I\big(1 + r^*(d)\big), \quad d \in [\underline{d}, \overline{d}],\ q \in \mathbb{R}_+$$

and the upper bound is reached for $i^G = i^B$. The definition of G then implies that

$$G\big(d, q, r^*(d)\big) \le d\big(1 + r^*(d)\big) \quad d \in [\underline{d}, \overline{d}],\ q \in \mathbb{R}_+ \tag{17}$$

This upper bound is reached when no bankruptcies occur. This yields the following Lemma:

Lemma 4
Let $d_\tau \in (\underline{d}, \overline{d}]$ for some arbitrary period τ and suppose that the shock q_τ is such that no bankruptcies occur. Then $d_{\tau+1} = \min\{d_\tau(1 + r^*(d_\tau)), \overline{d}\}$.

The preceding lemma shows that in good times, when aggregate productivity shocks are sufficiently positive, reserves increase according to the interest rate banks earn on reserves invested in the last period. Whether or not the banking system can survive will now depend on the increase of deficits or decrease of reserves in bad times.

Proposition 3
Suppose that the regulator never intervenes and that $r^*(0) > 0$. If $d_\tau < 0$ for some time τ, then the economy collapses with probability one.

Proof :
It follows from (17) and the monotonicity of r^* that

$$G\big(d, q, r^*(d)\big) \le d\big(1 + r^*(d)\big) \le d\big(1 + r^*(0)\big) < d, \quad d \in [\underline{d}, 0),\ q \in \mathbb{R}_+.$$

Therefore, if $d_\tau < 0$ for some time τ, then the deficit will be below $\underline{d}$ after a sufficient number of periods, because $r^*(d)$ is greater than zero. Hence, the economy collapses with probability 1.

■

Corollary 2

Suppose that $d_\tau = 0$ for some time τ and $\big(1 + i^G(0)\big)\, q_{crit} f(e+I)/I < 1 + r^*(0)$ for some shock $q_{crit} > 0$. If $\mathbb{P}(q \leq q_{crit}) > 0$, then the economy collapses with probability one.

Proof :

It follows from the condition on the average return on debt and (13) that $i^B > i^G$ and hence $P\big(0, q, r^*(0)\big) < I[\eta - i^G(0)]$ with positive probability. The ergodicity of the shock process implies that $d_t < 0$ for some finite time $t > \tau$ with probability 1.

■

Note that we have assumed that depositors do not take the possibility of a collapse into account and always save S. The above statements can therefore be reinterpreted as a contradiction to this assumption. Proposition 3 and the corollary illustrate that the banking system cannot recover from the losses and that the economy will collapse with certainty once losses have occurred. An important implication of the corollary is that the economy collapses with certainty if banks have a pay-out ratio $\beta = 1$ because all reserves would be distributed implying $d = 0$ reserves. In the following we assume $\beta = 0$, i.e., banks keep all reserves on their balance sheet. This is the best case for the survival of the banking system. Again, note that regulatory intervention is needed because managers and shareholders would prefer to pay out all reserves.

Suppose now that the banking system starts with some level of reserves. Will it also collapse? The answer to this question is crucial for the assessment of capital adequacy regulations. Suppose that the banking system has reserve levels satisfying a capital requirement rule at a particular point in time. Then, the regulator is interested in the capacity of the banking system to go through periods with repeated macroeconomic shocks. As we know from Proposition 3, the system without regulation will collapse with certainty as soon as deficits occur. Let T_0 denote the first time deficits occur, i.e. $d_{T_0} < 0$. If this event occurs with probability one, meaning that $\mathbb{P}(T_0 < \infty) = 1$, then, as a consequence, the economy itself collapses with probability one.[15] Sufficient conditions for this case are given in the following proposition.

Proposition 4

Let $r^*(0) > 0$ and suppose that the expected average repayment per unit of loan

[15]Technically, T_0 defines an optional time, see Appendix 11.

satisfies

$$\mathbb{E}[G(d, \cdot, r^*(d))] < d \quad \textit{for all } d \in [0, \overline{d}]. \tag{18}$$

Then, for any initial level of $d_0 \in [0, \overline{d}]$, $\mathbb{P}(T_0 < \infty) = 1$ *and the economy collapses with probability one.*

Proof :
Since $\mathbb{E}\big[G(d, \cdot, r^*(d))\big]$ is continuous with respect to d, a positive constant $c > 0$ exists such that

$$\mathbb{E}\big[G\big(d, \cdot, r^*(d)\big)\big] < d - c, \qquad \text{for all } d \in [0, \overline{d}].$$

Moreover, the process $\{d_t\}_{t \in \mathbb{N}}$, is uniformly integrable with respect to $\mathbb{P}$ (see Appendix 11 for a definition), because each $G\big(\cdot, q, r^*(\cdot)\big)$, $q \in \mathbb{R}$ is a continuous function on the compact interval $[\underline{d}, \overline{d}]$. Hence, the process $\{-d_t\}_{t \in \mathbb{N}}$ is a submartingale satisfying the hypotheses of Lemma 6, Appendix 11. This gives $\mathbb{P}(T_0 < \infty) = 1$ and Proposition 3 implies that the economy collapses with probability 1.

■

Proposition 4 implies that an initial level of reserves cannot prevent a collapse, if the decline of reserves in downturns is higher than the increase in upturns because of interest gains. According to Lemma 3, Assumption (18) is equivalent to saying that if firms' repayments are too low on average, then the economy collapses with certainty. Whether or not the assumption holds depends on the productivity level of firms, the distribution of macroeconomic shocks and on the magnitude of the interest rates. In the next section we show that the regulator can always prevent a collapse of the economy when intervention is sufficiently strong.

6.2 Avoidance of collapse

In this section we show that a complete breakdown of the economy can, in principle, always be avoided. In order to avoid such a collapse, a regulator has to be able to keep all future deficits above $\underline{d}$ with certainty. This requires that

$$G(d, \underline{q}, r^{dreg}) \geq \underline{d}, \quad d \in [\underline{d}, \overline{d}]. \tag{19}$$

It follows from Lemma 2 and (17) that a critical deficit level $d^{crit} \geq \underline{d}$ exists with

$$G\big(d^{crit}, \underline{q}, r^*(d^{crit})\big) = \underline{d}. \tag{20}$$

Without restriction, let d^{crit} be the largest level for which the consumption trap is reached. This implies that for any $d \leq d^{crit}$ there is a strictly positive probability for a collapse of the economy. Therefore, the deficit level d^{reg} which prompts the regulator to intervene in order to avoid a collapse with certainty has to be greater than d^{crit}. The next proposition characterizes policy rules ψ that prevent complete bankruptcies.

Proposition 5

Let d^{reg} be defined by (20) and ψ be a policy rule satisfying

$$1 + \psi(d) \leq \frac{-\underline{d}}{I[\eta - i^G(d)] - d} \quad \textit{for} \;\; d \in [\underline{d}, d^{reg}]$$

and $\psi(d) = r^*(d)$ for $d \in (d^{reg}, \overline{d}]$. Then, for the given intermediation game, a collapse can be avoided.

Proof :
By Lemma 2 (ii) it suffices to consider the worst possible case $\underline{q} = 0$. From the definition of the map G it follows that (19) holds for $\underline{q} = 0$ if ψ satisfies the conditions of the proposition.

■

Proposition 5 shows that a regulator can avoid a complete bankruptcy of the economy by setting $r^{dreg} = \psi(d)$ appropriately. It follows from the definition of $\underline{d}$ that $\psi(d) \geq 0$ for all $d \in [\underline{d}, \overline{d}]$. Moreover, no further assumptions on the loan interest rates are needed. Having established the collapse without intervention and the possibility of avoiding a collapse with certainty, we next examine the consequences of intervention rules focusing entirely on the avoidance of collapse.

7 The Consumption Trap

In this section we consider intervention rules that prevent an economy from a collapse in the sense of (19). A natural interpretation of such rules is that each generation can freely determine its intervention rule, but wants to avoid a collapse in order to protect its depositors. Assume that the young generation will determine the regulator policy. It is clear that the young generation will not intervene as long as the deficit level is less than d^{reg} where $d^{reg} = d^{crit}$ is the largest reserves level satisfying (20). For levels less than d^{reg}, they will set r^{dreg} so high that the deficit in the worst case, i.e. when $\underline{q}$ is realized, is still larger than $\underline{d}$ and hence can still be covered by new funds in the next period.

Proposition 6

Let $r^*(0) > 0$ and suppose that the intervention rules are set under the condition that an economic collapse will be avoided with probability 1. Then, if $d_\tau \leq d^{reg}$ for some time τ, the economy converges to the consumption trap $\underline{d}$ with positive probability.

Proof :
For simplicity,[16] consider the case $\underline{q} = 0$ and let d^{reg} be defined by (20). Since $r^*(0) > 0$ and r^* is decreasing, it follows from Lemma 2 that

$$G\big(d, 0, r^*(d)\big) \leq \underline{d} \leq G(d, 0, 0) \quad \text{ for all } d \in [\underline{d}, d^{reg}].$$

Since G is continuous with respect to r^{dreg}, a critical interest rate $r^{crit}(d)$ exists such that $\underline{d} = G\big(d, 0, r^{crit}(d)\big)$ for $d \in [\underline{d}, d^{reg}]$. Define an intervention rule by

$$\psi^{crit}(d) = \begin{cases} r^{crit}(d) & \text{ if } d \in [\underline{d}, d^{reg}] \\ r^*(d) & \text{ if } d \in (d^{reg}, \overline{d}] \end{cases}. \tag{21}$$

Less intervention would risk a collapse. More intervention would lower interest rates on savings and raise loan rates, which decreases the utility of consumers and entrepreneurs of the current generation. As soon as $d_\tau \leq d^{reg}$, there is a positive probability for reaching the consumption trap. This completes the proof.

■

Proposition 6 has important implications for the design of intervention rules. Even if each young generation intervenes sufficiently to avoid a collapse, the outcome may be highly inefficient over time. Although depositors are fully protected, aggregate income is very low because no profitable investments can be financed anymore. Stronger intervention rules than those that avoid a collapse are needed to avoid the consumption trap with certainty. If each generation can freely determine the regulator policy, the economy might end up in the consumption trap. Therefore, the discretion of a generation to determine regulatory intervention must be limited in order to avoid the consumption trap. This could occur through constitutional political arrangements which e.g. may give the old generation veto power restricting the regulators freedom to alter previously adapted fiscal policies (see e.g. Azariadis & Galasso 1998). Since, however, an old generation is indifferent to the intervention rules adopted by the new generation as long as a collapse is avoided, a strict incentive of the old generation to vote against less stringent intervention rules by the new generation must be born by the concern for future unborn generations.

In order to avoid the consumption trap, the regulator has to be able to keep all future deficits strictly above $\underline{d}$ with certainty. Following Proposition 5, policy rules ψ exist such that $G\big(d, \underline{q}, \psi(d)\big) > \underline{d}$ for all $d \in (\underline{d}, \overline{d}]$ with equality holding for $d = \underline{d}$. Now, in order to prevent the deficits from converging to $\underline{d}$, a policy rule ψ is needed such that

$$G\big(d, q, \psi(d)\big) > d$$

at least for deficit levels d close to $\underline{d}$ and sufficiently large shocks q. Using the definition of G, this condition is equivalent to the existence of ψ which satisfies

$$1 + \psi(d) < \frac{P\big(d, q, \psi(d)\big) - d}{[\eta - i^G(d)]I - d} \tag{22}$$

[16]The proof of the case $\underline{q} > 0$ is more tedious, but follows the same lines.

for small $d > \underline{d}$ and sufficiently large q. As long as the average repayment per unit loan is greater than unity, i.e.

$$\frac{P\big(d,q,\psi(d)\big)}{I[\eta - i^G(d)]} > 1,$$

Condition (22) can be satisfied by setting $\psi(d) = 0$. A sufficient condition for this is that the average return on debt of the entrepreneur with the highest quality level is greater than unity, $(1+\eta)qf(e+I)/I > 1$.

Lemma 5

Let $(1+\eta)q^\star f(e+I)/I > 1$ *for some* $q^\star \in \mathbb{R}_+$. *If* $\mathbb{P}(q \geq q^\star) > 0$, *then there exists a policy rule* ψ, *preventing the consumption trap with probability* 1.

Proof :

Using Proposition 5, there exists a policy rule ψ which avoids a collapse. Moreover, the assumption on the average productivity of the economy implies that ψ can be chosen such that $G\big(d,q,\psi(d)\big) > d$ for all sufficiently small $d \in (\underline{d}, d^\star]$ and all $q \geq q^\star$ for a suitable $d^\star > \underline{d}$. The ergodicity of the shock process then implies that the event $q_\tau \geq q^\star$ for some finite time τ occurs with probability one. Hence $d_t > \underline{d}$ for all times t with probability one. As a consequence, deficits will never converge to $\underline{d}$.

■

Lemma 5 shows that setting $r^{dreg} = \psi(d)$ sufficiently small prevents the economy from converging to the consumption trap. The economy may become arbitrarily close to the trap, but since there are sufficiently many good shocks with positive probability, where repayments are higher than deposit obligations per unit of investment, deficits will eventually be reduced and kept strictly above $\underline{d}$ with certainty. As pointed out above, potential losses due to bankruptcies decrease with the critical quality level i^G. However, this does not imply that generations are better off with lower values of d. Since Y is monotonically increasing in d for any realization of the shocks, later generations will always benefit from interventions by their predecessors that help prevent the deterioration of d as much as possible.

8 Reversing Bad and Preserving Good Times

In this section, we discuss the interventions necessary to reverse bad and to preserve good times. Bad times means that the economy has accumulated deficits whose levels lie in the interval $[\underline{d}, 0]$. Good times means that the banking system has accumulated reserves whose levels lie in $[0, \overline{d}]$. Reversing bad times requires that the regulator can decrease the current deficit by deposit rate control. Preserving good times requires that the regulator is able to sustain the current level of reserves by intervention. In the case of reserves, we assume again that $\beta = 0$, meaning that banks do not pay out reserves as dividends. This is the best they can do for sustaining good times.

8.1 Reversing bad times

Suppose that $d_\tau \le d^{reg}$ has been realized at time τ so that the regulator takes action. The regulator's task must be to compensate potential losses due to bad shocks by lowering deposit interest rates and thereby raising loan interest rates. In order to reverse bad times, the regulator not only has to be able to prevent the consumption trap but also to reduce the current deficit. Thus, we seek a policy rule ψ so that

$$G\big(d, q, \psi(d)\big) > d, \quad d \in (\underline{d}, d^{reg}]$$

with high enough probability. The next proposition shows that bad times can be reversed if average repayments are high enough.

Proposition 7
Let $d^{reg} \ge 0$ and $\underline{q} > 0$. Assume that a policy rule ψ exists which avoids a complete collapse and, in addition, satisfies the following conditions:

(i) ψ avoids the consumption trap in the sense of Lemma 5, i.e., there exists $d^\star > \underline{d}$ such that for each $d \in (\underline{d}, d^\star]$, $G\big(d, q, \psi(d)\big) > d$ with positive probability.

(ii) Expected future deficits satisfy $\mathbb{E}\left[G\big(d, \cdot, \psi(d)\big)\right] > d$ for all $d \in (\underline{d}, d^{reg}]$.

Then bad times can be reversed with probability one for any initial level of $d_0 \in (\underline{d}, \overline{d}]$.

Proof :
Since each $G\big(\cdot, q, \psi(\cdot)\big)$ is a continuous function on the compact interval $[\underline{d}, \overline{d}]$, (i) implies that there exists some finite time τ such that $d_t > d^\star$ for all $t \ge \tau$ with probability one. Since $\mathbb{E}\big[G(d, \cdot, \psi(d))\big]$ is continuous with respect to d, Assumption (ii) implies that a positive constant $c > 0$ exists so that

$$\mathbb{E}\big[G\big(d, \cdot, \psi(d)\big)\big] > d + c, \qquad \text{for all } d \in [d^\star, d^{reg}].$$

The process $\{d_t\}_{t \in \mathbb{N}}$, is uniformly integrable with respect to $\mathbb{P}$ (see Appendix 11 for a definition), because each $G\big(\cdot, q, \psi(\cdot)\big)$, $q \in \mathbb{R}$ is a continuous function on the compact interval $[\underline{d}, \overline{d}]$. Hence, $\{d_t\}_{t \ge \tau}$ is a submartingale satisfying the hypotheses of Lemma 6, Appendix 11. This implies that bad times can be reversed with probability 1.

■

First, observe that firm's repayments are positive as long as $\underline{q} > 0$. Therefore, Condition (i) in Proposition 7 is satisfied if ψ is sufficiently small for deficits close to $\underline{d}$. Second, in terms of Lemma 3, Condition (ii) states that expected average repayments have to be high enough in order to reverse bad times.

8.2 Preserving good times

We state the conditions necessary for preserving good times, in which reserves can be kept within the interval $[0, \overline{d}]$. This requires a policy rule ψ to satisfy

$$G\big(d, q, \psi(d)\big) \geq 0, \quad \text{for all } \ d \in [0, \overline{d}], \ q \geq \underline{q}.$$

This condition is equivalent to

$$1 + \psi(d) \leq \frac{P\big(d, \underline{q}, \psi(d)\big)}{[\eta - i^G(d)]I - d}, \quad d \in [0, \overline{d}], \tag{23}$$

implying that the lowest shock $\underline{q}$ must be greater than zero. Since reserve levels are positive, a sufficient condition for (23) is that the interest factor is less than the average repayment per unit of loan in the worst case, i.e.

$$1 + \psi(d) \leq \frac{P\big(d, \underline{q}, \psi(d)\big)}{[\eta - i^G(d)]I}, \quad d \in [0, \overline{d}]. \tag{24}$$

Assume that the policy rule ψ is non-decreasing. Then the RHS of (24) is non-increasing in d by Lemma 2. Since repayments of firms P are non-increasing in interest factors, we have the following.

Proposition 8
Let $\underline{q} > 0$, and assume that $P(\overline{d}, \underline{q}, 0) \geq \eta I$. Then there exists a policy rule ψ, such that good times are preserved with certainty.

A sufficient condition for Proposition 8 is that in the worst case the average repayment per unit of loan must still be greater than unity. Hence Lemma 2 gives a clear indication that preserving good times requires higher productivity of firms than for reversing bad times. Overall, the section illustrates that apart from exogenous shocks and regulation policies, the productivity of firms has a decisive influence on whether or not an economy can be kept in a healthy state concerning the banking system.

9 An Example

In this section we illustrate some of the results and general relationships by an example which allows for an explicit solution. Consider a concrete example, in which the shock process $\{q_t\}_{t \in \mathbb{N}}$ is i.i.d. and uniformly distributed on the compact interval $[\underline{q}, \overline{q}] \subset \mathbb{R}_+$. Set $\underline{r} = (1+i)\underline{q}f(e+I)/I - 1$ and $\overline{r} = (1+i)\overline{q}f(e+I)/I - 1$. Then the expected profit $\Pi(i, r)$ of entrepreneur i is

$$\Pi(i, r) = \begin{cases} (1+i)f(e+I)\frac{\overline{q}+\underline{q}}{2} - I(1+r) & \text{if } r \leq \underline{r} \\ \frac{(1+i)f(e+I)}{2(\overline{q}-\underline{q})}\left[\overline{q} - \frac{I(1+r)}{(1+i)f(e+I)}\right]^2 & \text{if } \underline{r} < r < \overline{r} \\ 0 & \text{if } \overline{r} \leq r \end{cases} \tag{25}$$

A straightforward calculation shows that the equilibrium interest rate r^* is

$$1+r^* = \begin{cases} \frac{(1+i^G)f(e+I)}{e+I}\frac{\overline{q}+\underline{q}}{2} & \text{if } \frac{I}{e} \leq \frac{2\underline{q}}{\overline{q}-\underline{q}} \\ \frac{(1+i^G)f(e+I)\overline{q}}{I}\left[1+\frac{\overline{q}-\underline{q}}{\overline{q}}\frac{e}{I} - \sqrt{\left(1+\frac{\overline{q}-\underline{q}}{\overline{q}}\frac{e}{I}\right)^2-1}\right] & \text{otherwise.} \end{cases} \tag{26}$$

i^G denotes the critical entrepreneur as before. In the regulated case $r^{dreg} \leq r^*$, the loan interest rates compute as

$$1+r^{c*} = \begin{cases} \frac{(1+i^G)f(e+I)}{I}\frac{\overline{q}+\underline{q}}{2} - \frac{e}{I}(1+r^{dreg}) & \text{if } \frac{I}{e} \leq \frac{2\underline{q}}{\overline{q}-\underline{q}} \\ \frac{(1+i^G)f(e+I)\overline{q}}{I}\left[1-\sqrt{\frac{2(\overline{q}-\underline{q})e}{(1+i^G)f(e+I)\overline{q}^2}(1+r^{dreg})}\right] & \text{otherwise.} \end{cases} \tag{27}$$

It follows from (13) that there are no bankruptcies, i.e. $i^B = i^G$, for the case $I/e \leq 2\underline{q}/(\overline{q}-\underline{q})$. This implies in particular that good times can be preserved by reducing the credit volume, provided $\underline{q} > 0$.

Consider the case $I/e > 2\underline{q}/(\overline{q}-\underline{q})$. Substituting (27) into (13) yields

$$i^B(d,q,r^{reg}) = \max\left\{i^G(d), \min\left\{\eta, \frac{q_{\mathrm{NB}}(d,r^{dreg})}{q}\big(1+i^G(d)\big)-1\right\}\right\}, \tag{28}$$

where the critical level q_{NB}, above which no bankruptcies occur, is given by

$$q_{\mathrm{NB}} = q_{\mathrm{NB}}(d,r^{dreg}) = \begin{cases} \overline{q}\left[1+\frac{\overline{q}-\underline{q}}{\overline{q}}\frac{e}{I} - \sqrt{\left(1+\frac{\overline{q}-\underline{q}}{\overline{q}}\frac{e}{I}\right)^2-1}\right] & \text{if } r^{dreg} = r^* \\ \overline{q}\left[1-\sqrt{\frac{2(\overline{q}-\underline{q})e}{\big(1+i^G(d)\big)f(e+I)\overline{q}^2}(1+r^{dreg})}\right] & \text{if } r^{dreg} < r^*. \end{cases}$$

This implies $i^B = i^G$ whenever $q \geq q_{\mathrm{NB}}$. Notice that $q_{\mathrm{NB}} < \overline{q}$ and that q_{NB} is independent of the reserve level in the unregulated case. Moreover, q_{NB} is increasing in I in both the unregulated and the regulated case. Using (12) and (28), the time-one map (15) is well defined. On the other hand, total bankruptcy of all firms $i^B = \eta$ obtains if and only if

$$q \leq q_{\mathrm{TB}}(d,r^{dreg}) := q_{\mathrm{NB}}(d,r^{dreg})\frac{\big(1+i^G(d)\big)}{1+\eta}.$$

This event will occur with positive probability whenever $\underline{q} < q_{\mathrm{TB}}(d,r^{dreg})$.

Let us demonstrate that an unregulated banking system that starts with the maximal level of reserves $\overline{d}$ may indeed collapse. Equations (12) and (26) imply

$$G\big(\overline{d},\underline{q},r^*(\overline{d})\big) = \underline{q}f(e+I)\eta(1+\tfrac{\eta}{2}) - S\,\tfrac{f(e+I)q_{\mathrm{NB}}}{I},$$

whenever $i^B = \eta$. Hence $G\big(\overline{d},\underline{q},r^*(\overline{d})\big) < 0$ for sufficiently small $\underline{q}$. Hence, the ergodicity of the shock process implies that the unregulated economy will collapse with certainty, if $\underline{q}$ is small enough.

10 Conclusion

In this paper we have explored the possibilities of protecting a banking system that is subject to repeated macroeconomic shocks from a collapse and the consumption trap. Our main conclusion is that both the intervention rules and the productivity of firms must be sufficiently strong in order to prevent the economy from periods with low aggregate income. Our analysis highlights that banking crises can lead to long-lasting economic downturns.

While the present analysis suggests that a dynamic general equilibrium perspective of the banking system is important for regulatory purposes, numerous issues deserve further scrutiny. In particular, there is need for a comprehensive investigation of the three pillars of regulation: the competitive framework, the deposit insurance with bail-out schemes, and the prudential supervision. Our model can be extended with respect to all of these three pillars. Concerning the first, we have focused on Bertrand competition of banks. An important question is whether less intensive competition among banks is a useful alternative to intervening regulators. Limited competition entails higher intermediation margins and thus allows for faster accumulation of reserves which in turn relieves the collapse and consumption trap problem. On the contrary, however, this will depress investments and lower aggregate incomes at any level of reserves. Concerning the second, deposit insurance was assumed to be costless for banks. An alternative arrangement would be to introduce explicit deposit insurance schemes which might lessen the need for intervention in a banking system with deposit rate controls.

Concerning the third pillar, the regulator might try to strictly enforce capital requirements in every period instead of controlling the deposit rates. This would force banks to decrease their loans on the books which, in turn, could lower aggregate income. Most likely, such a strict enforcement of capital requirements would only accelerate the collapse of the banking system. However, it is unclear whether a combination of capital requirements and deposit rate controls which depend on the business cycle could avoid banking crises at lower costs in terms of aggregate income than deposit rate controls alone. The answers to those and other questions are important for the assessment of the scope of government intervention in the banking sector and for the design of a socially desirable form of banking regulation.

11 Appendix: Sub- and Supermartingales

The purpose of this section is to review some standard facts about martingales and establish a useful lemma for our analysis. To this end let $\{X_t\}_{t\in\mathbb{N}}$ be a real-valued stochastic process on the probability space $(\Omega, \mathcal{F}, \mathbb{P})$ adapted to a filtration of sub-σ-algebras $\{\mathcal{F}_t\}_{t\in\mathbb{N}}$ of $\mathcal{F}$. Let $\mathbb{E}_t[X_{t+1}]$ denote the conditional expectation of X_{t+1} with respect to $\mathcal{F}_t$. The process $\{X_t\}_{t\in\mathbb{N}}$ is called *submartingale* if for all $t \in \mathbb{N}$

$$\mathbb{E}_t[X_{t+1}] \geq X_t, \quad \mathbb{P} - \text{a.s.}$$

$\{X_t\}_{t\in\mathbb{N}}$ is called a *supermartingale* if $\{-X_t\}_{t\in\mathbb{N}}$ is a submartingale. Thus it suffices to consider the submartingales.

A stochastic process $\{X_t\}_{t\in\mathbb{N}}$ is called *uniformly integrable* with respect to $\mathbb{P}$ (see, e.g. Bauer 1992, p. 138) if an integrable function $g \geq 0$ on Ω exists for each $\epsilon > 0$ such that

$$\int_{\{|X_t|\geq g\}} |X_t| \, d\mathbb{P} \leq \epsilon, \quad t \in \mathbb{N}.$$

It is straightforward to see that $\{X_t\}_{t\in\mathbb{N}}$ is uniformly integrable if there exist an integrable function $g \geq 0$ with $|X_t| \leq g$ $\mathbb{P}$-a.s. for all $t \in \mathbb{N}$. The following refinement of Doob's first convergence theorem is found in Bauer (1991, p. 164).

Proposition 9

Let $\{X_t\}_{t\in\mathbb{N}}$ be a submartingale. Then the following is equivalent:

(i) $\{X_t\}_{t\in\mathbb{N}}$ *converges $\mathbb{P}$-a.s. to a random variable X_∞ with $\mathbb{E}[X_\infty] < \infty$ such that $\{X_t\}_{t\in\mathbb{N}\cup\{\infty\}}$ is a submartingale and* $\lim_{t\to\infty} \mathbb{E}[X_t - X_\infty] = 0$.

(ii) $\{X_t\}_{t\in\mathbb{N}}$ *is uniformly integrable.*

(iii) $\{X_t\}_{t\in\mathbb{N}}$ *converges in means, i.e.,* $\lim_{t\to\infty} \mathbb{E}[X_t - X_{t-1}] = 0$.

Let $\alpha \in \mathbb{R}$ be arbitrary and $T_\alpha : \Omega \to \mathbb{N}$ be an *optional time*, given by

$$T_\alpha(\omega) = \inf\{t \in \mathbb{N} \mid X_t(\omega) \geq \alpha\}, \quad \omega \in \Omega.$$

T_α describes the first time the process $\{X_t\}_{t\in\mathbb{N}}$ is above the threshold α with the understanding that $\inf \emptyset = \infty$. Consider a family of sets of the form

$$A_t := \{\omega \in \Omega : \ X_s(\omega) < \alpha, \ s \leq t\}, \quad t \in \mathbb{N}. \tag{29}$$

Clearly $A_t \in \mathcal{F}_t$ and $A_t \supset A_{t+1}$ for all $t \in \mathbb{N}$. The set $A := \cap_{t\in\mathbb{N}} A_t$ is the event that the process $\{X_t\}_{t\in\mathbb{N}}$ stays strictly below the threshold α for all times t. This means that $\{T_\alpha < \infty\} = \Omega \setminus A$. The following lemma shows when this event has probability one.

Lemma 6

Let $\{X_t\}_{t\in\mathbb{N}}$ be a uniformly integrable submartingale. Assume, in addition, that there is a strictly positive constant $c > 0$ such that for each $t \in \mathbb{N}$,

$$\mathbb{E}_t[X_{t+1}(\omega)] - X_t(\omega) \geq c > 0, \quad \omega \in A_t. \tag{30}$$

Then $\mathbb{P}(T_\alpha < \infty) = 1$.

Proof :

We have to show that $\mathbb{P}(A) = 0$. Following Proposition 9, an integrable random variable X_∞ exists such that the process converges in means, i.e. $\lim_{t\to\infty} \mathbb{E}[X_t - X_\infty] = 0$.

Moreover, the sequence of indicator functions $(\chi_{A_t})_{t\in\mathbb{N}}$ associated with the sets (29) is monotonically decreasing, which implies that

$$\lim_{t\to\infty} \mathbb{P}(A_t) = \lim_{t\to\infty} \int \chi_{A_t}\, d\mathbb{P} = \mathbb{P}(A).$$

This implies that

$$\lim_{t\to\infty} \int \chi_{A_t}(X_{t+1} - X_t)\, d\mathbb{P} = 0.$$

On the other hand, using (30) and $A_t \in \mathcal{F}_t$, we obtain

$$\int_{A_t} (X_{t+1} - X_t)\, d\mathbb{P} = \int_{A_t} (\mathbb{E}_t[X_{t+1}] - X_t)\, d\mathbb{P} \geq c\,\mathbb{P}(A_t), \quad t \in \mathbb{N}.$$

Since the l.h.s. tends to zero for $t \to \infty$ and $c > 0$, $\mathbb{P}(A) = \lim_{t\to\infty} \mathbb{P}(A_t) = 0$.

■

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